## **CLAIMS**

## What is claimed:

- [c01] A slurry coating composition for providing aluminum content to the surface region of a metal-based substrate, wherein the composition is substantially free of hexavalent chromium, and comprises colloidal silica and particles of an aluminum-based powder.
- [c02] The composition of claim 1, wherein the aluminum-based powder has an average particle size in the range of about 0.5 micron to about 200 microns.
- [c03] The composition of claim 1, wherein the aluminum-based powder comprises an alloy of aluminum and silicon.
- [c04] The composition of claim 3, wherein the silicon is present in an amount sufficient to decrease the melting point of the aluminum-silicon alloy to below about 610°C.
- [c05] The composition of claim 3, wherein the silicon is present at a level in the range of about 1% by weight to about 20% by weight, based on the combined weight of the silicon and aluminum.
- [c06] The composition of claim 5, wherein the silicon is present at a level in the range of about 10% by weight to about 15% by weight, based on the combined weight of the silicon and aluminum.
- [c07] The composition of claim 3, wherein the aluminum-silicon alloy comprises substantially spherical powder particles.
- [c08] The composition of claim 1, further comprising a liquid carrier selected from the group consisting of water, alcohols, halogenated hydrocarbon solvents, and compatible mixtures thereof.

- [c09] The composition of claim 8, further comprising an effective amount of at least one additive selected from the group consisting of thickening agents, dispersants, deflocculants, anti-settling agents, anti-foaming agents, binders, plasticizers, emollients, surfactants, and lubricants.
- [c10] The composition of claim 1, containing less than about 10% by weight of phosphoric acid and phosphoric acid derivatives, based on the weight of the entire composition.
- [c11] An aqueous-based slurry coating composition according to claim 1.
- [c12] The composition of claim 1, wherein the colloidal silica is present at a level in the range of about 5% by weight to about 20% by weight, based on silica solids as a percentage of the entire composition.
- [c13] The composition of claim 1, wherein the amount of aluminum in the slurry composition exceeds the amount of aluminum present in the substrate by up to about 65 atomic %.
- [c14] The composition of claim 1, wherein the aluminumbased powder further comprises at least one metal selected from the group consisting of platinum group metals, rare earth metals, scandium, yttrium, iron, chromium, and cobalt.
- [c15] The composition of claim 1, wherein the silica in the colloidal silica has an average particle size in the range of about 10 nanometers to about 100 nanometers.
- [c16] The composition of claim 1, further comprising at least one organic compound which contains at least two hydroxyl groups.

- [c17] The composition of claim 16, wherein the organic compound contains at least three hydroxyl groups.
- [c18] The composition of claim 16, wherein the organic compound is selected from the group consisting of alkane diols, glycerol, pentaerythritol, fats, and carbohydrates.
- [c19] The composition of claim 18, wherein the carbohydrate is a sugar compound.
- [c20] The composition of claim 16, wherein the organic compound is present in an amount sufficient to chemically stabilize the aluminum-based powder during contact with any aqueous component present in the composition.
- [c21] The composition of claim 16, wherein the organic compound is present at a level in the range of about 0.1% by weight to about 20% by weight, based on the total weight of the composition.
- [c22] A slurry coating composition for providing aluminum to the surface region of a turbine component formed from a material comprising a nickel-based superalloy, wherein the composition is substantially free of hexavalent chromium, and comprises colloidal silica and particles of an aluminum-silicon alloy which has an average particle size in the range of about 1 micron to about 50 microns.
- [c23] The composition of claim 22, wherein the colloidal silica is present at a level in the range of about 5% by weight to about 20% by weight, based on silica solids as a percentage of the entire composition; and the amount of aluminum in the composition exceeds the amount of aluminum present in the surface region of the component by up to about 65 atomic %.
- [c24] A slurry coating composition for providing aluminum to the surface region of a turbine component formed from a material comprising a

nickel-based superalloy, wherein the composition is substantially free of hexavalent chromium, and comprises colloidal silica; an organic stabilizer which contains at least two hydroxyl groups; and particles of an aluminum-based powder which has an average particle size in the range of about 1 micron to about 50 microns.

- [c25] The composition of claim 24, wherein the organic stabilizer is selected from the group consisting of glycerol, at least one dihydroxy alcohol, and combinations thereof.
- [c26] The composition of claim 24, wherein the aluminum-based powder comprises an alloy of aluminum and silicon.
  - [c27] The composition of claim 24, wherein

the organic stabilizer is present at a level in the range of about 0.1% by weight to about 20% by weight, based on the total weight of the composition;

the colloidal silica is present at a level in the range of about 5% by weight to about 20% by weight, based on silica solids as a percentage of the entire composition; and

the amount of aluminum in the composition exceeds the amount of aluminum present in the surface region of the component by up to about 65 atomic %.

- [c28] A method for aluminiding the surface region of a metal substrate, comprising the following steps:
- (I) applying at least one layer of a slurry coating to the surface of the substrate; wherein the slurry coating is substantially free of hexavalent chromium, and comprises colloidal silica and particles of an

aluminum-based powder, and the aluminum-based powder has an average particle size in the range of about 0.5 micron to about 200 microns; and

- (II) heat treating the slurry coating, under conditions sufficient to remove volatile components from the coating, and to cause diffusion of aluminum into the surface region of the substrate.
- [c29] The method of claim 28, wherein the aluminum-based powder in the slurry coating comprises an alloy of aluminum and silicon.
- [c30] The method of claim 28, wherein the slurry coating further comprises an organic stabilizer which contains at least two hydroxyl groups.
- [c31] The method of claim 30, wherein the organic stabilizer is selected from the group consisting of alkane diols, glycerol, pentaerythritol, fats, and carbohydrates.
- [c32] The method of claim 30, wherein the aluminum-based powder in the slurry coating comprises an alloy of aluminum and silicon.
- [c33] The method of claim 28, wherein the slurry coating is applied to the surface of the substrate by a technique selected from the group consisting of spraying, slip-casting, brush-painting, dipping, pouring, rolling, and spin-coating.
- [c34] The method of claim 28, wherein the heat treatment of step (II) comprises a preliminary heat treatment to remove the volatile components, and a final heat treatment to diffuse the aluminum into the substrate.
- [c35] The method of claim 28, wherein the heat treatment is carried out at a temperature in the range of about 650°C to about 1100°C.

- [c36] The method of claim 28, wherein step (II) comprises a graduated heat treatment.
- [c37] The method of claim 28, wherein the surface region of the substrate extends to a depth of about 200 microns into the substrate.
- [c38] A method for aluminiding the surface region of a nickel-based superalloy substrate, comprising the following steps:
- (I) spraying at least one layer of a slurry coating on the surface of the substrate; wherein the slurry coating is substantially free of hexavalent chromium, and comprises colloidal silica; particles of an aluminum-based powder; and an organic stabilizer, wherein the aluminum-based powder has an average particle size in the range of about 0.5 micron to about 200 microns; and the organic stabilizer is selected from the group consisting of alkane diols, glycerol, pentaerythritol, fats, and carbohydrates; and then
- (II) heat treating the slurry coating in an oven at a temperature of about 650°C to about 1100°C, so as to remove volatile components from the coating, and to cause diffusion of aluminum into the surface region of the substrate;

wherein the organic stabilizer is present at a level in the range of about 0.1% by weight to about 20% by weight, based on the total weight of the composition;

the colloidal silica is present at a level in the range of about 5% by weight to about 20% by weight, based on silica solids as a percentage of the entire composition; and

the amount of aluminum in the composition exceeds the amount of aluminum present in the substrate by up to about 65 atomic %.

- [c39] The method of claim 38, wherein the substrate is a turbine engine component.
- [c40] A method for preparing an aluminum-based slurry coating composition, comprising the following steps:
- a) combining an organic stabilizer with an aluminum-based powder, in the presence of a limited amount of aqueous colloidal silica, so as to form a uniform, stabilizer-aluminum pre-blend, wherein the amount of aqueous colloidal silica present is high enough to ensure adequate blending of the stabilizer and the aluminum-based powder, but low enough to ensure that the pre-blend remains chemically-stabilized; and then
- b) combining a second portion of the aqueous colloidal silica with the stabilizer-aluminum pre-blend formed in step (a), to form a chemically-stable slurry coating composition.
- [c41] A metal substrate, having a slurry coating disposed on its surface, said coating being free of hexavalent chromium, and comprising colloidal silica and particles of an aluminum-based powder.
- [c42] The metal substrate of claim 41, wherein the aluminum-based powder comprises an alloy of aluminum and silicon.
- [c43] The metal substrate of claim 41, wherein the slurry coating further comprises at least one organic compound which contains at least two hydroxyl groups.
- [c44] The metal substrate of claim 41, comprising a turbine engine component formed of a nickel-based superalloy.